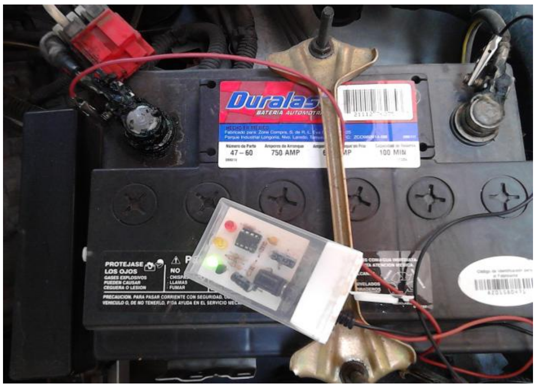
Car Battery/charging system diagnostics

PART NO. 2192106



You can hook up the kit's test leads directly to the car battery (with engine off) and see whether battery voltage is ok (green LED on) or low (yellow LED on).

Actual testing begins when you start the car. The starter draws a lot of current so while cranking, the yellow LED should come on indicating that voltage is low but still good. If the red LED comes on while cranking and/or does not start at all, this indicates that battery may need recharging or the battery needs to be replaced if the red LED still comes on after recharging.

Once the engine starts, the green LED should start blinking for half a second on and half a second off. This indicates that the alternator is charging the battery. While the engine runs idle, you can turn head lights on, A/C on, radio on, windshield wipers on, etc. and green LED should continue blinking indicating that alternator is charging the battery properly.

Run the engine at about 2000 rpm with the above mentioned loads on and green LED should continue blinking. In the event red LED starts blinking, this indicates that battery is being overcharged which could damage the battery and corrective action should be taken.

Only one LED comes on at any given time which makes it easy to interpret the results.

Time Required: 1 hour depending on experience

Experience Level: Intermediate

Required tools and parts:

1 - Soldering iron and solder
1 - Clip-on heat sink (Jameco P/N: 159126)
1 - Needle nose pliers
1 - Diagonal cut pliers
1 - Automobile Fused Power Plugs with cords Jameco P/N: 124760
2 - Connector Power PL 2 Position straight cable mount Jameco P/N: 191484
6 - feet cable 18 AWG
1 - Pair alligator clips, one red, one black. Jameco P/N: 70991
1 - 1 oz tic tac empty box

Bill of Materials:

Qty	Jameco SKU	Component Name
3	691104	10K 1/4W resistor 5%
R1,R6, R7		
1	690988	3.3K 1/4W resistor 5%
R2		
3	690742	330 Ohm 1/4W resistor 5%
R3, R4, R5		
1	93739	22uF 50V Electrolytic 20%
C1		
1	198839	10uF 16V Electrolytic 20%
C2		

1	198839	10uF 16V Electrolytic20%
C3		
1	35991	1N4004 400 PRV 1A
D1		
1	693901	Green LED 5mm
LED1		
1	697696	Yellow LED 5mm
LED2		
1	697522	Red LED 5mm
LED3		
1	51182	Standard Regulator 5 Volt 0.14 Amp 3 Pin TO-92 Box
IC2		
1	765302	Preprogrammed MCU 8-bit ATtiny
IC1		
1	51571	Socket IC 8-pin
8 Pin DIP IC Socket		
1	101178	Jack DC Power Male 2.1 mm
J1 Connector Jack DC Power male		

Step 1 - Verify parts are complete

Resistors

3 - 330 Ohm 1/4W 5% resistors R3, R4, R5
1 - 3.3K 1/4W 5% resistor R2
3 - 10K 1/4W 5% resistors R1, R6, R7

Capacitors

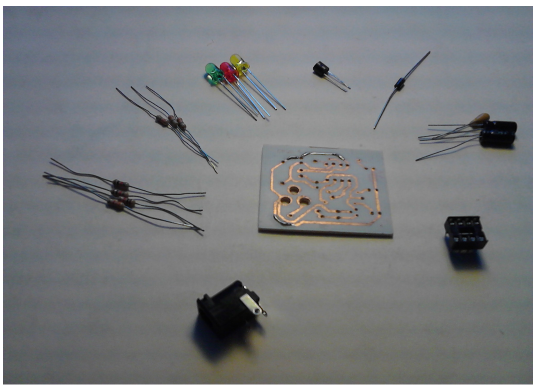
1 - 22uF 25V Electrolytic cap C1
2 - 10uF 16V Electrolytic cap C2, C3

Semiconductors

1 - 1N4004 400V 1A rectifier D1
1 - Green LED 5mm LED1
1 - Yellow LED 5mm LED2
1 - Red LED 5mm LED3
1 - ATtiny 13 ATMEL microcontroller IC1
1 - 78L05 +5V regulator IC2

Miscellaneous

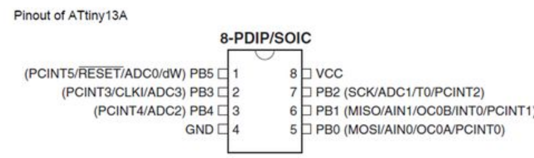
1 - DC Jack Connector J1
1 - 8-pin IC socket
1 - Printed Circuit Board



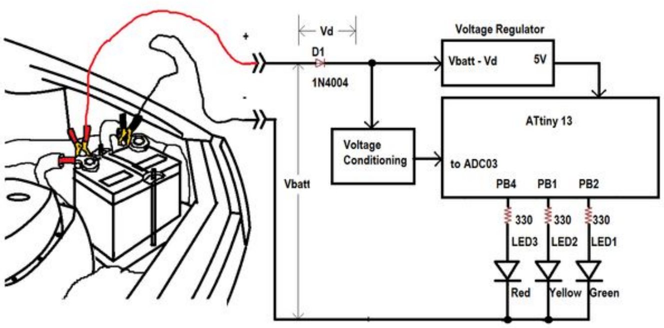
Main Features

- Designed for 12V car battery electrical systems.
- Easy to program through Arduino.
- Simple 8 pin IC microcontroller.
- Compact, fits inside an empty Tic-Tac 1oz box.
- Can test battery in engine compartment.
- Can monitor battery status through cigarette lighter receptacle.
- Protection against polarity reversal
- Inexpensive.

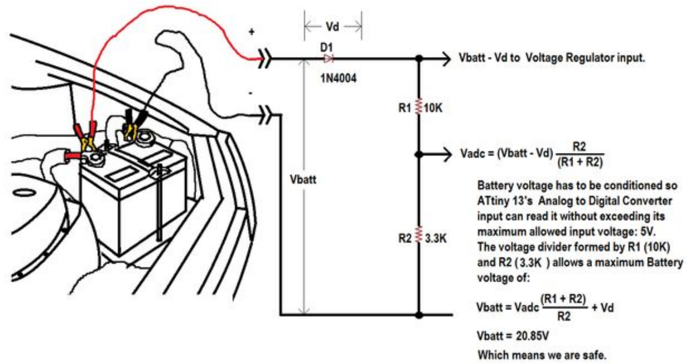
ATMEL ATtiny 13



Car Battery Monitor Block Diagram

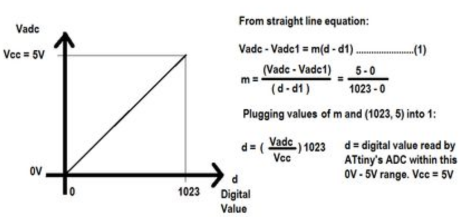


Analog input Voltage conditioning circuit



ATtiny Analog to Digital Conversion process

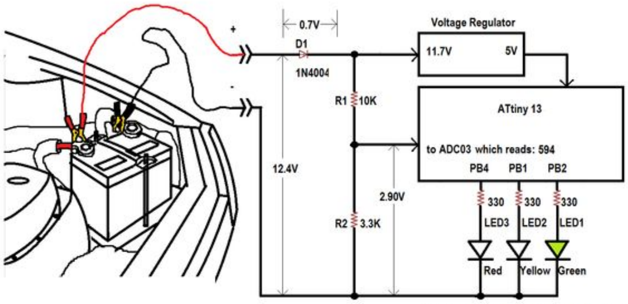
- The ADC converts an Analog input voltage to a 10-bit digital value through Successive Approximation.
- The minimum value (0) represents GND potential (0V) and the maximum value (1023) represents Vcc (+5V).



First test with engine off.

- Visually inspect battery terminals for corrosion.
- Check –with your hands- whether terminals are loose.
- If everything above is correct, hook up battery monitor across battery terminals.
- Battery monitor will turn green LED on if battery voltage is between 12.4V and 13.1V.
- If yellow LED comes on instead, this means battery voltage is low.

A fully charged battery should have 12.6V across its terminals. With engine off, if voltage is between 12.4V and below 13.1V, green LED should come fully on indicating normal battery voltage.



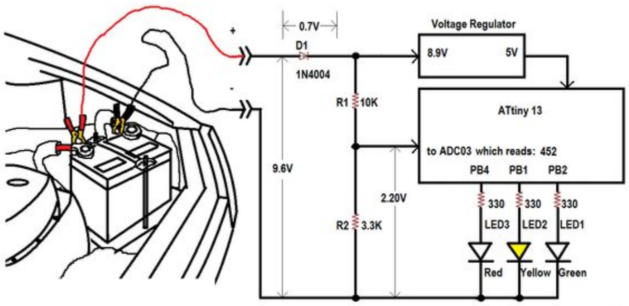
When battery voltage is between 12.4V and below 13.1V, green LED will come fully on.

Cranking engine test

- This battery monitor cannot test for Cold Cranking Amps so we'll start the engine instead.
- While cranking, only yellow LED should come on.
- If red LED comes on briefly, battery may be bad even if engine starts and green LED comes back on. Either get your hands dirty or have a mechanic do a voltage drop test before dooming battery.

With engine off: If battery voltage is below 12.4V, yellow LED will come on showing a low voltage condition. If engine does not start, recharge battery.

While cranking engine: A good battery would cause yellow LED to come on. If red LED comes on even after battery has been recharged, replace battery.

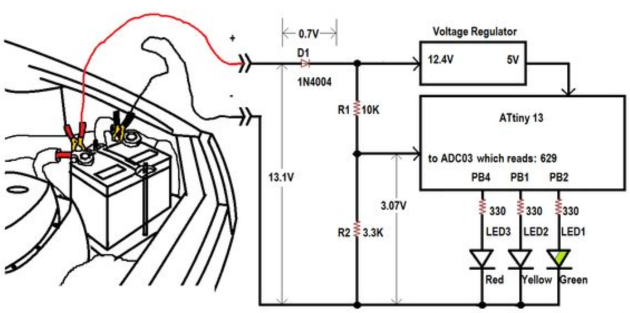


When battery voltage is between 9.6V and less than 12.4V, yellow LED will come fully on. If voltage falls below 9.6V, yellow LED will go out and red LED will come fully on.

Once engine started

- Green LED should be blinking on and off. If it does not blink or worse, yellow light comes on, alternator may be bad.
- With green LED blinking, turn on A/C, radio, headlights, etc. except rear defogger.
- Green LED should remain blinking on and off which proves alternator is doing its job.
- If Green LED stays on without blinking, get your hands dirty or have a mechanic do a voltage drop test between battery and alternator.

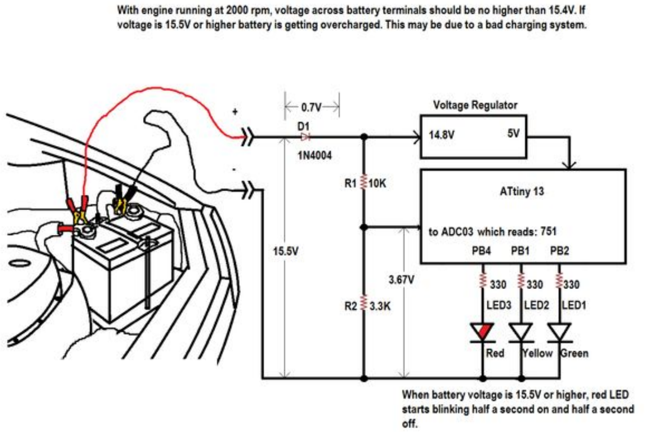
With engine running idle and most loads on, battery voltage should be at least 13.1V. This proves alternator is charging battery.

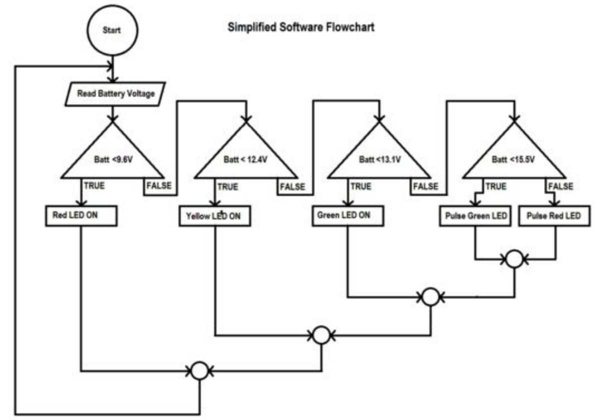


When battery voltage is between 13.1V and 15.4V, green LED blinks half a second on and half a second off.

Overcharge test

- Turn on A/C, radio, headlights, windshield wiper, etc. except rear defogger.
- Run the engine to at least 2,000 rpm.
- Green LED should be blinking.
- If Red LED starts blinking, this means alternator is overcharging battery which could be caused by a faulty voltage regulator.





The Schematic Diagram

Battery voltage gets into the battery monitor through connector J1. Diode D1 is used to protect the entire circuit against accidental battery polarity reversal in case you decide to test the battery directly across its terminals in the engine compartment. Should you connect the test alligator clips reversed, nothing will happen.

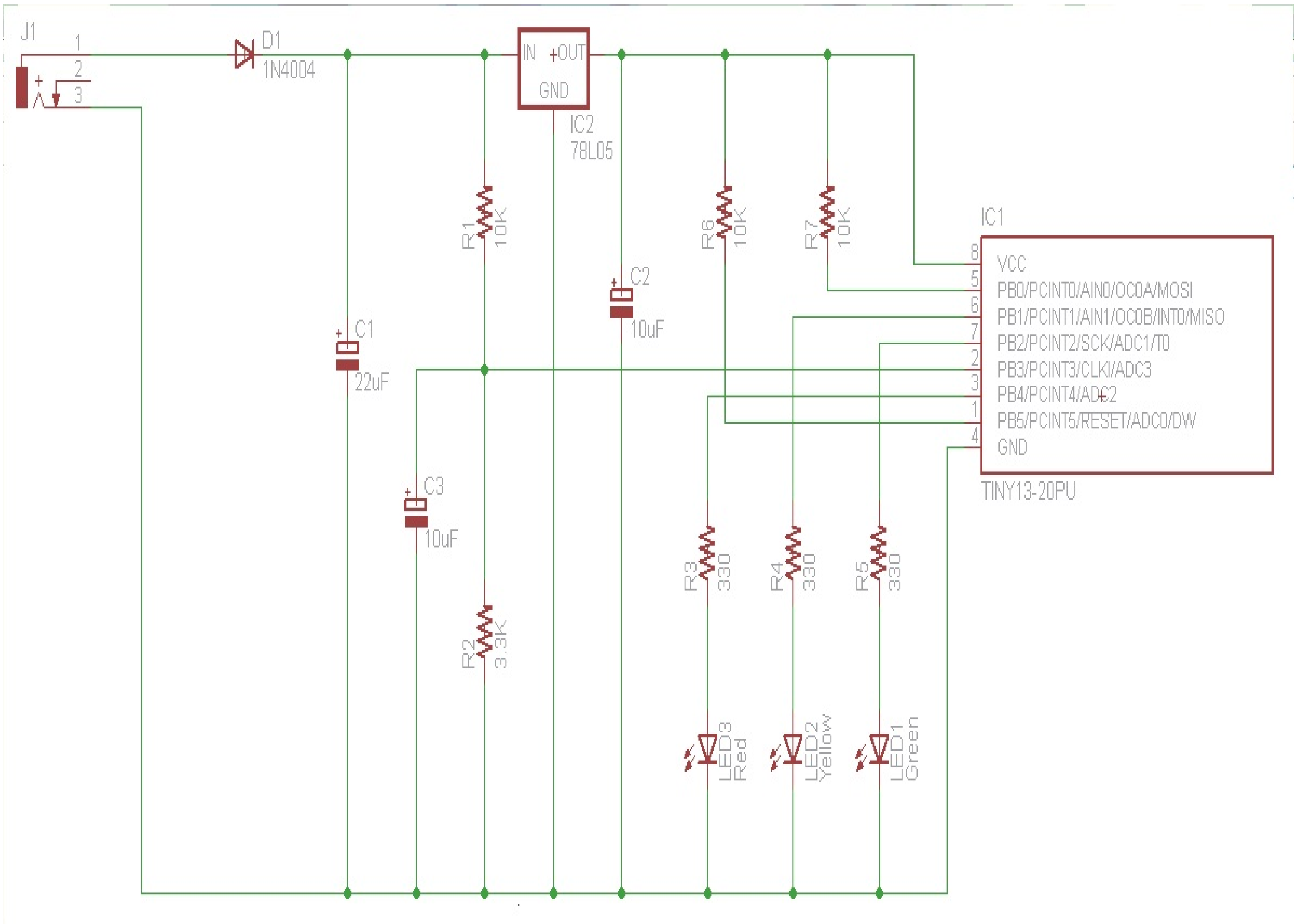
IC2 is a +5V low dropout voltage regulator. Its input voltage range –with a 100mA load- varies between 5.4V up to its absolute maximum of 30V. I admit that for this battery monitor a 78L05 +5V voltage regulator would have been more than enough, however, I had no 78L05s and several LP2950CZA-5.0 kicking around in my junk box.Capacitors C1 and C2 (22uF and 1uF) are voltage regulator’s input and output filters. If you want to use pin-compatible 78L05 voltage regulator instead, use a 10uF capacitor as C2.

The battery voltage feeds both, the voltage regulator and the ADC input circuit to ATtiny through a voltage divider formed by a 10K resistor and a 3.3K resistor marked as R1 and R2 respectively. This voltage divider is used to reduce battery voltage to a safe input voltage range between 0V and +5V for ATtiny’s analog input. This voltage divider allows a maximum car battery voltage of 20.8V for this input voltage range. In order to smooth out this analog input voltage, a 10uF (C3) is used to reduce noise.

The visual output to the user is shown by means of three LEDs. A Red LED (LED3) shows either too low a voltage or a dangerous overvoltage. A Yellow LED (LED2) shows a moderate low voltage and the green LED (LED1) shows good voltage and safe charging voltage. Each LED comes with its respective current limiter 330 Ohm resistors, R3, R4 and R5. Resistors R6 and R7 at 10K each are pull up resistors for unused inputs.

Step 2 - Schematic Diagram

See all components listed in bill of materials and how they are wired together to form the battery monitor.

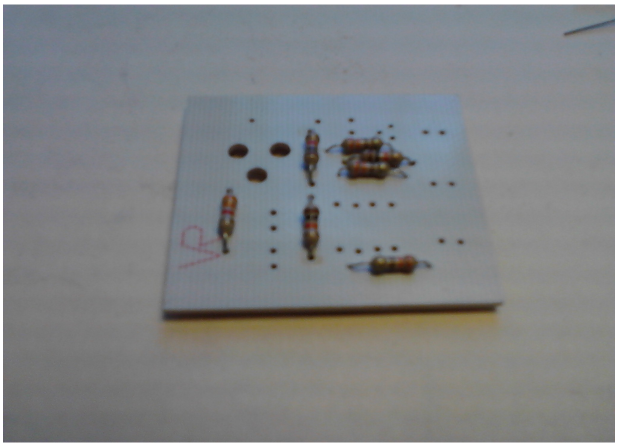


Step 3 - Solder in resistors

Start by locating a 10K 1/4 resistor and insert it into R1 position. Take the only 3.3K 1/4 resistor and place it into R2. Once these resistors are in place, solder in their leads to their solder pads. These resistors form a voltage divider that conditions battery input voltage to ATtiny 13 Analog to Digital converter.

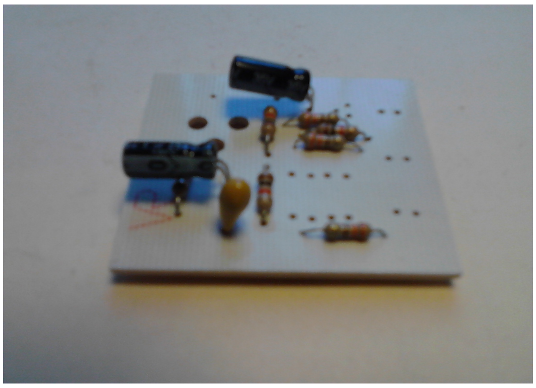
Now, locate three 330 Ohm 1/4 resistors and solder them in into R3, R4 and R5 positions. These resistors are used as current limiters for LED1, LED2 and LED3.

Last, take the remaining two 10K 1/4 resistors and solder them in place in R6 and R7 positions. The purpose of these resistors is to pull up unused inputs to +5V for proper operation of microcontroller.



Step 4 - Add capacitors

Place the 22uF capacitor C1 into its position, one 10uF capacitor into C2 and the other 10uF capacitor into C3 positions and solder them in place.



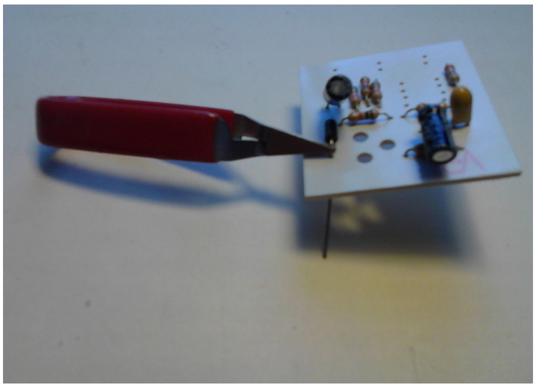
Step 5 - Install Semiconductors

Using a clip-on heat sink, solder in diode D1 observing polarity mark. Heat sink in picture is shown so heat is applied to this lead to reduce overheating the diode. Allow a few seconds for D1 to cool off then move clip-on heat sink to the other lead and do the same.

When soldering IC2, place the heat sink also on same lead that is to be soldered in and allow several seconds to cool off before moving on to next lead until you are done with all three leads.

Now, if you want the body of each LED to be touching the PCB, the heatsink won't fit between the body of LEDs and solder joint so you will have to be careful and solder each lead without heat sink as quickly as possible. Solder joint has to be done properly, though.

Insert green LED into LED1 position watching that cathode (the shorter lead) is facing to the edge of PCB and solder in place. Yellow LED goes into LED2 position and red LED into LED3 position. All cathodes facing towards the edge of PCB.

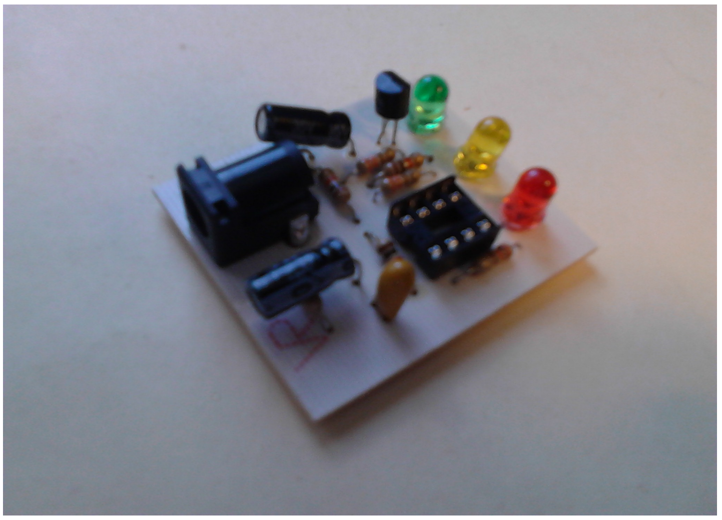


Step 6 - Install IC socket and DC Jack Power connector

Put 8-pin IC socket into U1 position making sure that index mark is properly oriented and solder in place. Be careful not to solder two adjacent pins together. If this happens, reheat with soldering iron and when solder melts wipe excess solder away. Make sure that pins are properly soldered.

Now, this part proved to be tricky, J1 connector comes with wide leads which called for oversized holes in the PCB. Place DC Jack power connector into J1 position making sure when PCB is with solder side up that connector does not fall off PCB. Get soldering iron and solder close to first solder joint you are about to make. Melt some solder on soldering iron tip making sure that the solder bead formed this way is slightly bigger than the space between J1 connector lead and its solder pad, then apply this solder to this solder joint making sure that solder stays in place and does not flow through the hole into component side of PCB. Repeat for the remaining two leads of J1 connector.

This completes assembly of this kit.



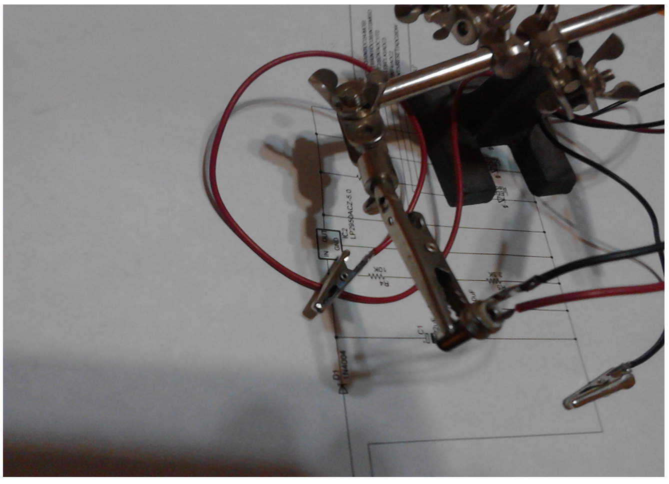
Step 7 - Assemble test probes

Grab one of the connectors Jameco P/N: 191484 and solder at least two feet of 18 AWG cable to each one of the two terminals as shown in the picture. The picture shows one red and one black segment soldered in into the connector's terminals. Your cable may be one color only. Grab the two alligator clips Jameco P/N: 70991 and solder in the red one to the other end of the wire soldered to the central terminal of connector P/N: 191484. Now, solder in the black alligator clip to the other wire, the one whose other end is soldered to the edge terminal of same P/N: 191484 connector.

Make sure that both terminals are not touching each other before putting the cover back on this connector.

Automobile Fused power plug

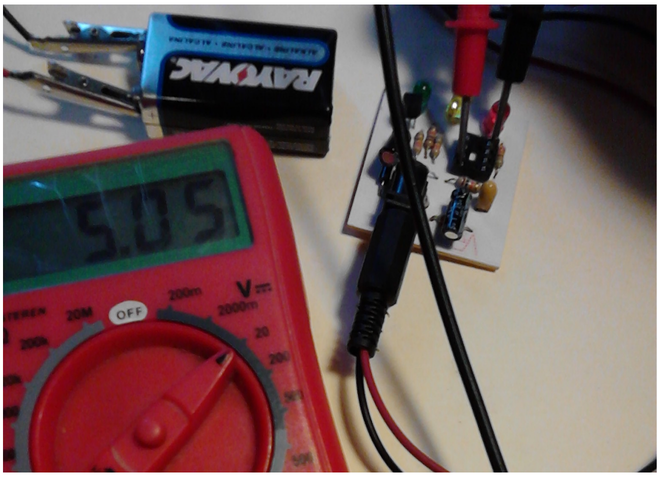
Jameco P/N: 124760 comes with a two wire cable whose ends are stripped. Using an Ohm meter, check continuity between the center terminal of this cigarette lighter connector and the two ends to find out which one is connected to it. Once center terminal's wire is located, solder it in into the center terminal of the second PL 2 position connector Jameco P/N: 191484. Solder in the remaining cable end to the edge terminal of same connector Jameco P/N: 191484 making sure both terminals don't touch to each other before putting the cover back on this connector.



Step 8 - Test Battery monitor Power supply

Before inserting ATtiny micro controller into its IC socket, let's make sure first that onboard power supply is working properly. Plug in the test probes assembled in previous step into onboard DC Power Jack. With a 9V battery, place red alligator clip on battery's positive terminal and black lead on negative. Using a multimeter set on DC Voltage, measure volts between U1 leads 4 and 8. Place multimeter's black test lead on terminal 4 (Gnd) of U1 and red test lead on terminal 8.(Vcc).

Voltage reading should be +5V as shown on attached picture (+5.05V). After completing this test, it's time to disconnect battery and prepare battery monitor for final test.



Step 9 - Final Test

Final Test

Insert pre-programmed ATtiny 13 MCU into U1 socket, making sure IC is properly oriented using index mark as a reference. Now, put in assembled battery monitor inside an empty Tic-Tac 1 oz box with LEDs side first in. Slide test probe plug through hole of Tic-Tac box lid and plug it in into DC power jack of PCB. Put lid in place.

*** Disclaimer ***

Car batteries can hold a huge amount of charge. Only trained car professional mechanics or experienced individuals should try testing directly on car battery terminals. Doing the following procedure across battery terminals is the sole responsibility of individual performing the tests.

The following procedures should be performed as described being extremely careful not to short circuit battery terminals together by any means. Failure to do so due to negligence, carelessness, etc may produce bodily injuries or death.

In order to reduce risks, individuals not experienced working inside car engine compartments must use automobile Fused Power plug for testing battery through cigarette lighter receptacle inside car instead.

End of Disclaimer

For trained car professional mechanics:

Pop up the hood of your car so you have access to the engine compartment. With engine off, hook up the black alligator clip to the negative (-) battery terminal. Now attach the red alligator clip to the positive (+) battery terminal. If battery voltage is Ok, green LED should come on. Green LED comes on and stays on (no blinking) when battery voltage is greater or equal to 12.4V and less than 13.1V. When a battery is fully charged, its voltage should be 12.6V but it may vary within the range given above.

Now, make sure your battery monitor and its test probe wires cannot get in the way of moving engine parts. Make sure parking brake is on and if your car has manual transmission, it is set to neutral. Most automatic cars will not even start if the transmission is not set to Parking. Then, have someone start the engine while you watch the monitor. Watch battery monitor carefully as engine starts. While engine is cranking, a good battery should cause yellow LED to come on. Once engine starts, green LED would come on but now it will start blinking at a rate of about half a second on and half a second off approximately.

Yellow LED comes on only when voltage is greater than or equal to 9.6V and less than 12.4V. As this is just a battery monitor, you can consider this cranking voltage test as a load test because the starter motor draws the greatest current the battery will ever supply compared to the other loads. While engine is cranking and if red LED ever comes on, this means your battery is either under charged or your battery is bad. If your starter just clicks or the engine is cranking too slowly and does not start, have the battery recharged. Once battery has been recharged, repeat the test. If engine starts but red LED still comes on while cranking, replace the battery.

For inexperienced individuals:

***While performing this initial test through the cigarette lighter adapter, there may not be any voltage with engine off unless the key is

turned to ACC position. Also, most cars we have tested through cigarette lighter adapter do not supply any voltage while cranking the engine, therefore, the battery monitor lights will go out and will not come on until engine starts.***

The following tests work with both types of test probes. Voltage drop tests should be performed by professional mechanics.

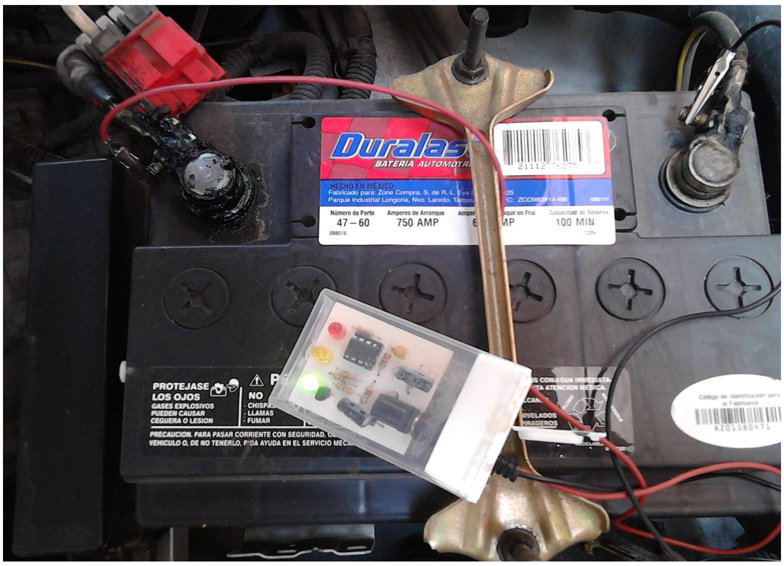
Charging Voltage

When engine is idle, green LED should be blinking at the rate mentioned above. This means battery voltage is at least 13.1V and green LED will blink while battery voltage is equal to or greater than 13.1V and less than 15.4V. For a charging test while engine is idle, turn on your A/C, radio, windshield wipers, headlights, etc. Once these loads are on, green LED should still be blinking which means your alternator can maintain charging voltage in spite of these loads drawing current.

If green LED stops blinking and stays fully on while this is going on, have a professional mechanic check your battery terminals for excessive voltage drop with a multi-meter. A voltage drop higher than 0.1V would be considered excessive and should be corrected. If voltage drop is about right and green LED remains on without blinking, measure the voltage with a good voltmeter so a reading of at least 13.1V should be obtained. If voltage is right, chances are the difference may be due to tolerance of components in your battery monitor. If voltage is less than 13.1V and no significant voltage drop is found then have your charging system checked by a professional. Chances are you have a bad alternator

Charging Voltage at 2,000 rpm

Have same loads as above turned on and run the engine to at least 2,000 rpm. Green LED should remain blinking. In the event red LED starts blinking at same rate given above, your alternator is overcharging your battery. This means that the system voltage regulator is not working properly. Again, have your system checked by a professional.



The Software:

The software was written based on the hints given by Eric-the-car-guy in this excellent video . He didn't mention the voltage at which a battery can be considered bad. However, my own car's service manual stated that while cranking the engine, voltage should not get lower than 9.6V. If it does, then battery should be replaced which seems to be about right for most car batteries.

This sketch is very simple, just a series of consecutive IF instructions to compare voltage read through ADC3 with some predefined values. If you follow the code closely, you'll see that the values shown in the Theory of Operation slide show in Step 1 are the same values used in the different IF instructions to decide which LED should come on.

To create the blinking effect on LEDs whenever voltages are higher than 13.1V, a counter is increased by one on every pass through that portion of the code. Before the code loops back to read ADC3 again, execution is delayed 100 milliseconds. IF instructions turn LEDs on whenever the pass counter is below 6 and turn LEDs off whenever counter is between 6 and 11. Once counter reaches 11, the counter is reset to zero to repeat the cycle.

ADC3 input is used to read the analog voltage coming from the voltage divider. By the way, ADC0 had been the first choice as this project's analog input, however, when voltage coming from the battery was a bit lower than 8.7V all three LEDs would go out. This didn't seem right as I had used a low-dropout voltage regulator. After doing some more research on the web I found that anytime you used a pin as an input that could also function as hardware Reset, these things could happen. Once ADC3 was selected as analog input, battery voltage could come down close to 6V and red LED would still be on which means the software would still be running. It was then that in order to prevent further problems, unused pins 1 and 5 were pulled up to +5V through 10K resistors.

ATtiny 13 code:

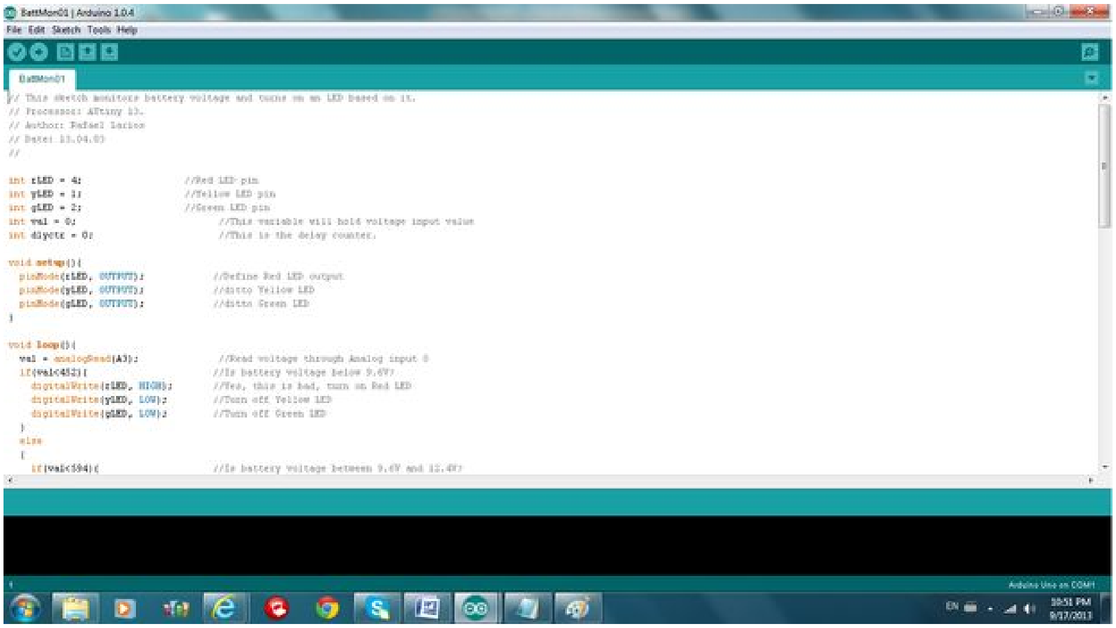
```
// This sketch monitors battery voltage and turns on an LED based on it.
// Processor: ATtiny 13.
// Author: rlarios
// Date: 13.04.03
//

int rLED = 4; //Red LED pin
int yLED = 1; //Yellow LED pin
int gLED = 2; //Green LED pin
int val = 0; //This variable will hold voltage input value
int dlyctr = 0; //This is the delay counter.

void setup(){
pinMode(rLED, OUTPUT); //Define Red LED output
pinMode(yLED, OUTPUT); //ditto Yellow LED
pinMode(gLED, OUTPUT); //ditto Green LED
}

void loop(){
val = analogRead(A3); //Read voltage through Analog input 3
if(val<452){ //Is battery voltage below 9.6V?
digitalWrite(rLED, HIGH); //Yes, this is bad, turn on Red LED
digitalWrite(yLED, LOW); //Turn off Yellow LED
digitalWrite(gLED, LOW); //Turn off Green LED
}
else
{
if(val<594){ //Is battery voltage between 9.6V and 12.4V?
digitalWrite(rLED, LOW); //This is a low voltage, turn off red LED
digitalWrite(yLED, HIGH); //Turn on Yelow LED as a warning.
digitalWrite(gLED, LOW); //Turn off Green LED
}
else
{
if(val<629){ //Is battery voltage between 12.4V and 13.1V while idle?
digitalWrite(rLED, LOW); //Yes, turn off Red LED
digitalWrite(yLED, LOW); //Turn off Yellow LED
digitalWrite(gLED, HIGH); //Turn on Green LED to indicate fully charged battery voltage.
}
else
{
dlyctr = dlyctr + 1; //increase delay counter. every pass approx. 100ms
if(val<751){ //Is battery voltage above 13.1V and below 15.5V?
digitalWrite(rLED, LOW); //Turn off red LED
digitalWrite(yLED, LOW); //Turn off yellow LED
if(dlyctr<6){
digitalWrite(gLED, HIGH); //Pulse green LED on for half a second
}
else
{
digitalWrite(gLED, LOW); //Pulse green LED off for half a second to show battery is charging.
if(dlyctr>10){
dlyctr=0; //Reset delay counter
}
}
}
else //Battery voltage is above 15.5V.Danger ! Overcharge
{
digitalWrite(yLED, LOW); //Turn off Yellow LED
digitalWrite(gLED, LOW); //Turn off Green LED
if(dlyctr<6){
digitalWrite(rLED, HIGH); //Turn on Red LED for half a second.
}
else
{
digitalWrite(rLED, LOW); //Turn off Red LED for half a second.
if(dlyctr>10){
dlyctr=0; //Reset delay counter
}
}
}
delay(100); //Stop program 100 milliseconds to help pulse LEDs.

}
}
}
}
```



Programming ATtiny 13:

You'll have to wire Arduino UNO and ATtiny 13 as shown in one of the images in this step. Make sure ATtiny 13 pin 1 is properly oriented. Once wiring is ready, you'll have to load Arduino IDE in your laptop computer and configure it so it can be used as a programmer.

I won't get into the details here about configuring Arduino UNO as ISP and where to get ATtiny 13's libraries. After some research I found this excellent video by Chris Stubbs on how to do just that. The video also shows how to wire Arduino UNO and ATtiny 13 together.

After Arduino UNO is configured to function as ISP, and ATtiny 13 libraries have been loaded, it is time to select our target "board". From Arduino IDE menu bar click on Tools>board> ATtiny 13 @9.6MHz (internal 9.6MHz clock). Next, type in the battery monitor sketch into Arduino IDE and proceed to compile it and upload it into ATtiny 13. The selection of ATtiny 13 with a 9.6MHz clock will cause the blinking rate of LEDs to have a period of about 1.4 seconds. This means, LED will be on 0.7 seconds and off 0.7 seconds which is close to what I originally intended.

We will put our Car Battery monitor together in the following steps.